The impact of EU carbon price changes on the stock performance of European electricity firms

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Abstract

This research investigates the relationship between EU Emission Allowance (EUA) price changes and the stock performance of European electricity firms. The EU Emission Trading Scheme began in 2005 as a cap and trade model to help meet the binding carbon emission reduction obligations set by the Kyoto Protocol. My research uses the empirical model of a previous study that had examined this relationship from 2006-2009 and extends it to 2010-2012. The model includes the market return, the change in electricity prices, the change in oil prices, and the change in EUA prices as factors determining the stock return of individual European electricity firms. Fundamental market valuation assumes that capital markets will value a firm at its expected discounted future profits. This analysis gives a lens into how capital markets believe the profitability of firms is impacted by the EU ETS. Results show that the relationship between carbon price changes and stock performance varies significantly between different firms and even within the same firm over time. For the majority of firms the correlation was positive over the 2010-2012 period, with the average carbon price coefficient equal to 0.007, higher than the 2006-2009 coefficient of -0.003. Results did not provide clear evidence for country-specific effects. Results also showed a lack of consistency in terms of the correlation over time, as it fluctuated back and forth between negative and positive on both the aggregate-level and individual firm-level.

I. Introduction

There have been considerable international policy efforts over the last twenty years to mitigate carbon dioxide (CO2) emissions, the most notable coming in 1997 with the Kyoto Protocol—an international agreement linked to the United Nations Framework Convention on Climate Change. The Kyoto Protocol commits its parties to reduce their greenhouse gas emissions by 8% of the 1990 level over the 2008 to 2012 period. EU authorities are responsible for making sure this overall cap on total emissions from all sectors of the economy in all 28 EU countries along with Iceland, Liechtenstein, and Norway is met. The European Union Emission Trading Scheme (EU ETS) is one mechanism used to help meet this goal. The scheme is a 'cap and trade' market-based approach to mitigate carbon emissions, allowing firms the flexibility to abide by the scheme in the most cost-effective way, buying and selling carbon permits, called European Union Allowances (EUAs), as needed. Each EUA gives its holder the right to emit one ton of carbon dioxide. More than 11,000 power stations and manufacturing plants, around 45% of total EU emissions, are limited by the EU ETS. The firms limited by the EU ETS are labeled as part of the "trading sector" and include those industries which are the largest emitters of carbon dioxide: electricity production, oil refining, heating and gas transportation along with major emitters in the industrial sector. Under the scheme, firms are allocated permits based on historical emission levels and then can trade these permits in the marketplace. At the end of each year every firm regulated by the scheme is responsible for owning enough allowances to cover their emissions for the past year. If all emissions are not accounted for with the appropriate amount of permits, a fine is administered per ton of CO_2 short.

The EU ETS is a decentralized cap and trade model with each country devising its own National Allocation Plan (NAP). These plans determine what fraction of each country's national emissions budget is allocated to the "trading" and "non-trading sectors", and how stringent the permit allocation process will be (Kruger et al., 2007). Countries such as Spain, Italy, and the UK have the most stringent caps meaning that firms in these countries are more likely to be allocated a smaller percentage of permits in relation to their observed emissions (Bushnell et al., 2012).

Phase I of the EU ETS began in 2005 and operated as a pilot period for every participant involved to get used to the scheme before the Kyoto binding Phase II period began in 2008. The transition to Phase II saw the share of free allocation of allowances decrease from 95% to 90% and the penalty for not having enough permits become much greater, increasing from 40€ per ton to 100€ per ton (Mo et al. 2012). The EU ETS started as and still is the largest international greenhouse gas (GHG) emission allowance market. The annual value of permits consumed in the market reached nearly €60 billion in 2012 (Bushnell et al., 2012). A sufficiently high carbon price should lead firms to shift generation to lower emitting plants and promote investment in clean, low-carbon technologies. Along with being a mechanism to help achieve the commitments required by the Kyoto Protocol, the design of the EU ETS is such that by 2020, the end of Phase III (2013-2020), carbon emissions from the sectors covered will be 21% lower than 2005 levels (EC Climate Action, 2013).

The implementation of this new regulation led to research investigating the potential economic consequences. Subjects of interest include how the EU ETS has impacted firms' profitability, investment decisions, and competition with other firms and industries along with what the optimal level of auctioning should be, what the optimal design of a country's National Allocation Plan should be, and whether the EU ETS is a cost-effective model.[1] Understanding

[1] Zachmann G and von Hirschhausen C (2008), Hoffmann VH (2007), Asselt HV, Biermann F(2007), Ellerman AD and Buchner B (2006)

the economic impacts of the EU ETS is not only important for having a better grasp on potential consequences in Europe, but for helping better design future carbon cap and trade systems in other parts of the world as well. One area of economic interest related to the EU ETS has been the financial market impact EUA price developments have had on the stock performance of firms. Several papers have specifically looked at the relationship between changes in EUA prices and the stock performance of European electricity firms, Oberndorfer (2009) and Mo et al. (2012). The electricity sector is the largest single source of emissions in the scheme, accounting for 57%, and will have to obtain the most permits, thus this sector is of great interest for research centered on the impacts of the EU ETS (Bushnell et al., 2012).

Fundamental market valuation assumes that capital markets will value a firm at its expected discounted future profits. Looking at the relationship between changes in EUA prices and stock performance provides a lens to see how investors believe firms' profits are affected by EUA prices. A decrease in EUA prices is equivalent to a relaxation of regulation. The structure of the scheme is such that most of the permits needed by firms, 95% in Phase I and 90% in Phase II, were grandfathered in, meaning they were allocated to firms freely based on historical emission levels. The initial permit net short / long position of a firm varied, depending on the country and industry it is a part of. The net position of a firm is significant in determining the impact the scheme has on profit. If a firm is in a net short position and the price of EUAs rises then this indicates an increase in compliance costs which could lead to a decrease in future profits. If a firm is in a net long position and the price of EUAs rises then this indicates an increase in potential revenue from selling the unneeded permits in the market at the now higher price, which would lead to an increase in future profits. The concept of windfall profits has been an issue related to the EU ETS, as there is concern that firms have been over-allocated permits allowing them to profit from the regulation. Another important factor to consider is the cost pass-through ability of the firm. Most EU member states were very explicit that the expected shortage of EUAs was to be assigned to the electricity sector because of the limited competition present in this sector along with the relatively inelastic demand for electricity (Ellerman et al., 2007). This would allow firms in this sector to more easily pass on EU ETS compliance costs to consumers through higher prices, which increases revenue, and possibly leaves profits largely unchanged by the increased costs and revenues balancing out. With a high enough EUA price, firms will also face the business decision of whether it would be more cost effective to switch to cleaner power generating methods, possibly from coal to natural gas. This investment decision would be associated with new fixed costs but lower EU ETS marginal compliance costs.

Following capital market theory, if there is a negative correlation between EUA price increases and stock performance of European electricity firms it can be assumed that when EUA prices increase, the expected future profits of the firm decrease. If there is a positive correlation it can be assumed that an increase in regulation leads to an increase in profit for European electricity firms. A correlation of zero would indicate that capital markets either believe the scheme changes the costs and revenues of the firm in such a way that the two balance out and profits remain unchanged or that the costs or revenue associated with the scheme are so negligible that they aren't taken into account when estimating future profits.

This paper will fill the current literature gap on the relationship between EUA price changes and the stock value of European electricity firms. To my knowledge, there have been no studies on this subject that look further than 2009, which is only two years into Phase II of the scheme. For my analysis, I use the model from the research conducted by Mo, Zhu, and Fan (2012) and extend it to study the entirety of Phase II. Previous literature has found there to be in general a positive correlation during Phase I, and the research specifically by Mo, et al. (2012) found a negative relationship to exist in the first two years of Phase II. Mo et al. (2012) also identified that the relationship between changes in EUA prices and stock performance varied significantly from one firm to the next.

There are two prevailing forces that I expect will influence the profitability of firms and thus my results during my period of interest, 2010-2012. I expect a downward pressure on correlation to be exerted from an increase in regulation stringency as the scheme continues to lower its cap and lower the amount of permits grandfathered in. I also expect an upward pressure to come from the fact that Europe, like most of the rest of the world, was dealing with a recession during this time period, leading to a decrease in demand for electricity which means less output and less emissions from electricity firms. If a firm's emissions totals are less than what was forecasted, a higher percentage of needed permits will be covered by those grandfathered to the firm, cutting compliance costs. Knowing that a surplus of permits has been a big concern related to the EU ETS, with the European Commission reporting that by the end of Phase II the surplus stood at almost two billion allowances, I believe this upward pressure on profits will outweigh the downward pressure of increased regulatory stringency (EC Climate Action, 2013). I expect the relationship between EUA price changes and stock performance of European electricity firms to be more positively correlated than the literature has shown it to be over the earlier time period. I expect that there will be country-specific stock market effects given the decentralized nature of the EU ETS, with firms in countries with more stringent allocation policies having lower carbon price coefficients, possibly even negative. I also expect to find consistency on a firm to firm basis over the entirety of Phase II, meaning I expect a firm to either have a positive correlation for the entirety of the phase or a negative one for the entirety of the phase.

II. Literature Review

This section will contain a discussion of previous literature that examined the financial market effects the EU ETS has on European electricity firms. The first econometric analysis on the stock market effects of the EU ETS was completed by Oberndorfer (2009). He used a multifactor market model to test the relationship between EUA price changes and the stock market return of 12 European electricity corporations, which included Aem (Italy — IT), British Energy Group (United Kingdom—UK), Eon (Germany—DE), Endesa (Spain—ES), Enel (IT), Energias de Portugal (Portugal), Fortum (Finland), Iberdrola (ES), International Power (UK), RWE (DE), Scottish & Southern Energy (UK), and Union Fenosa (ES). He included the market return, oil price changes, electricity price changes, and gas price changes as control variables in his model. The data used in the analysis spans from 2005 through 2007. He used a multitude of regression methods, including an ordinary least squares (OLS) process using an equal-weighted portfolio approach and a panel approach, as well as a Generalized AutoRegressive Conditional Heteroskedasticity (GARCH) model. These frameworks are augmented by including country-specific indicator variables in order to take into account country-specific stock market effects to EUA price developments. Interaction terms to take into account possible asymmetries were included as well to allow the model to be able to identify whether an increase in EUA prices had a different magnitude of effect on returns than an equal decrease in EUA prices. EUA settlement price changes were used, and Oberndorfer noted that although futures prices are less affected by very short run demand and supply fluctuations and therefore less noisy, he opted for spot prices because of the thin trading volume in the futures market during his period of analysis. Electricity prices from the German market were used as a proxy for overall EU electricity prices.

His results show a positive correlation between changes in EUA prices and stock performance of European electricity firms. The estimated carbon price beta estimate varies between regression models from 0.001 and 0.002, indicating that as EUA prices increase, the firms' stock value rises as well. Oberndorfer did not find evidence for an asymmetric reaction of electricity stock returns to EUA price changes. He did find though that the EUA effect on the stock market is country-specific with Spanish electricity firms exhibiting a slightly negative relationship and all other countries exhibiting a positive relationship, with UK firms having the most positive relationship.

In related research on the financial market effects of the EU ETS, Mo, Zhu, and Fan (2012) used a slightly different CAPM style model and regression method than Oberndorfer. They differ from Oberndorfer by excluding changes in gas prices as a control variable and by using futures prices from the IntercontinentalExchange (ICE) instead of spot prices from the European Energy Exchange (EEX). Mo, et al. accounts for the issues of thin initial trading volume in the EUA futures market by using a regression technique which implements lead and lag terms. The authors also looked at the relationship in a much more disaggregated manner than Oberndorfer. They ran separate regressions for each electricity firm to be able to see the relationship on a firm-specific level. They also ran separate regressions for each year of data spanning from 2006 through 2009 to investigate whether the relationship changed over time as the EU ETS evolved, moving from Phase I to Phase II. Like Oberndorfer, the authors looked at 12 firms, but a different mix, which included a2a (IT), Drax Group (UK), Électricité de France

(FR), Endesa (ES), Enel (IT), Fortum (FI), Iberdrola (ES), International Power (UK), Public Power Corporation (GR), Red Eléctrica de España (ES), Scottish & Southern Energy (UK), Terna Group (IT). To look at the results in a more generalized fashion they took the mean and median of their results.

Results indicated that the effect of a change in EUA prices on European electricity firm returns varied significantly from firm to firm. When aggregated, the beta coefficient for EUA price changes had a mean of -0.014 and a median of -0.002. For Phase I, the mean was 0.006 and for Phase II the mean was -0.0334. These results suggest that the increase in regulation stringency in Phase II caused an increase in EUA prices to lead to depreciation in corporate value instead of appreciation in value like it had done in Phase I. The higher absolute value also indicated that firms had a higher sensitivity to EUA price changes in Phase II.

Research by Bushnell, Chong, and Mansur (2012) investigated the ways in which firms can profit from regulation, specifically looking at the implementation of the EU ETS. New regulation impacts both costs and revenues in a multitude of ways causing the profitability puzzle to be complex. This research took an event study approach, investigating the potential for abnormal returns on firms contained in the Dow Jones STOXX 600 index in late April 2006 when there was a sharp devaluation of EUA prices. The authors provide a theoretical model which considered the factors of firm profitability that changes in EUA prices could impact. The model included consumer demand, the cost of producing electricity, the value of EUAs in possession, the cost of compliance, and the cost of abatement. The model is intended to be general, encompassing both perfectly competitive industries and those in which individual firms have market power (Bushnell et al., 2012).

Results showed that the sharp devaluation in EUA prices impacted sectors differentially, and that the sectors that emit the most CO2 performed the worst during the event. The authors believed this indicates that the higher emitting sectors, which the electricity sector is a part of, are able to profit from the regulation associated with the EU ETS. The authors also noted that the results of their study indicate that equity markets are strongly focused on revenue effects associated with EUA prices.

III. Empirical Framework

My research uses a multifactor model in accordance with Mo et al. (2012). The factors used in this model to explain the stock performance of European electricity firms are the market return, changes in electricity prices, changes in oil prices, and the factor of primary interest, changes in EUA prices. The market return is included because as suggested by the Capital Asset Pricing Model (CAPM), the risk-to-reward ratio of any security in relation to that of the overall market is the decisive factor for the pricing of the individual security. Previous literature concludes that oil is one of the main indicators for energy-price developments as a whole, and so oil price changes are included as a control variable here (Oberndorfer, 2009). Electricity price changes are included because electricity is the main product of the companies we are analyzing. Mo et al. (2012) cited previous literature that had shown there to be a significant relationship between the stock returns of a firm and the price of the firm's main product. EUA price changes are included because the relationship between EUA prices and the value of European electricity companies is the main focus of this research. Like Mo et al. (2012), I analyze the stock returns of these corporations in disaggregated form allowing the identification of firm-specific EUA effects. Daily data was used to estimate OLS regressions. Infrequent or thin trading, which was present during the initial pilot phase of the EU ETS, can result in problems with coefficient estimates (Sercu, 2007). To alleviate this problem, the authors incorporated lead and lag terms for the independent variables and I do this as well. The result is a multifactor market model which can be expressed as follows:

(1) $$R_{i,t} = \alpha_i + \beta_{im}^{-1} R_{m,t-1} + \beta_{im}^{0} R_{m,t} + \beta_{im}^{+1} R_{m,t+1} + \beta_{ie}^{-1} R_{e,t-1} + \beta_{ie}^{0} R_{e,t} + \beta_{ie}^{+1} R_{e,t+1} + \beta_{io}^{-1} R_{o,t-1} + \beta_{io}^{0} R_{o,t} + \beta_{io}^{+1} R_{o,t+1} + \beta_{ic}^{-1} R_{c,t-1} + \beta_{ic}^{0} R_{c,t} + \beta_{ic}^{+1} R_{c,t+1} + \epsilon_{i,t}$$

where $\epsilon_{i,t}$ is a disturbance term with $E(\epsilon_{i,t})=0$ and $var(\epsilon_{i,t}) = \sigma^2$ and α_i is a constant. $R_{i,t}$ is the stock market return of the individual European electricity firms. $R_{m,t-1}$, $R_{e,t-1}$, $R_{o,t-1}$, and $R_{c,t-1}$ are the lag terms for market return, electricity price changes, oil price changes, and carbon price changes respectively. $R_{m,t}$, $R_{e,t}$, $R_{o,t}$, and $R_{c,t}$ are the synchronous terms for market return, electricity price changes, oil price changes, and carbon price changes respectively. $R_{m,t+1}$, $R_{e,t+1}$, $R_{o,t+1}$, and $R_{c,t+1}$ are the lead terms for market return, electricity price changes, oil price changes, and carbon price changes respectively. The βs are the OLS estimates of the coefficients on the variables in the model. The aggregate coefficient estimates are calculated by adding the lag, synchronous, and lead beta estimates for each variable:

$$\beta_{im} = \beta_{im}^{-1} + \beta_{im}^{0} + \beta_{im}^{+1}$$

$$\beta_{ie} = \beta_{ie}^{-1} + \beta_{ie}^{0} + \beta_{ie}^{+1}$$

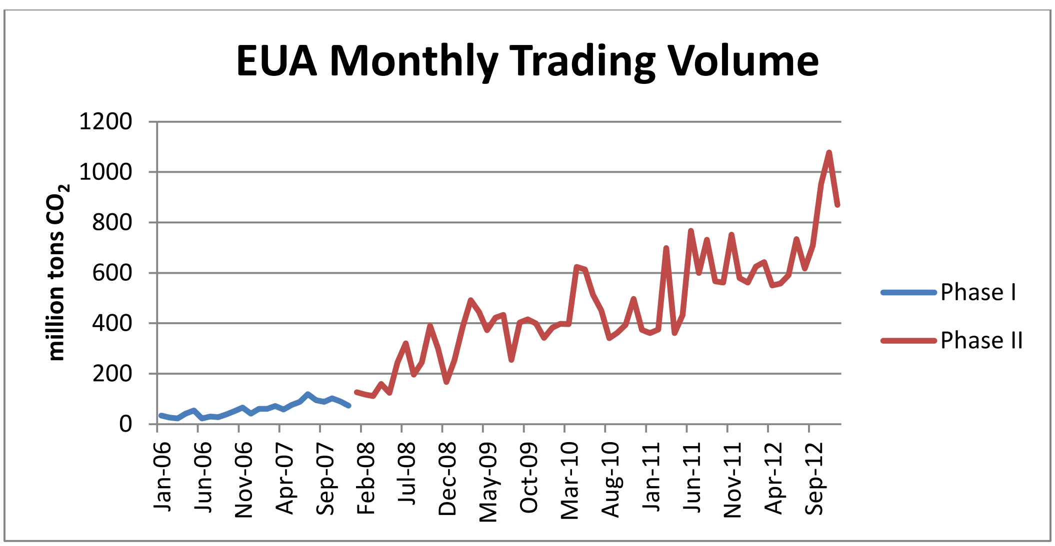
$$\beta_{io} = \beta_{io}^{-1} + \beta_{io}^{0} + \beta_{io}^{+1}$$

$$\beta_{ic} = \beta_{ic}^{-1} + \beta_{ic}^{0} + \beta_{ic}^{+1}$$

A positive value of β indicates that the variable has a positive correlation with the stock performance of the firm. The model is estimated for each European electricity firm in one year blocks. The mean and median of the individual companies' β series were calculated to obtain an aggregate market interpretation. I replicate Mo et al. (2012) to the extent possible. I then extend the research to the new time period of interest, 2010-2012. In total I will run 84 (12 firms*7 years) individual regressions.

I will also run a slightly modified model of Mo, et al. (2012), which will include three additional European electricity firms CEZ Group (Czech Republic--CZ), E.ON (Germany—DE), and RWE (DE). I include these three because they all have significant market share in the European electricity sector (Convery, 2007). The two German electricity firms were also added because there were no German firms represented in the study by Mo et al., which appears to be a serious omission given that Germany firms were awarded roughly half the total EU cap in permits (Convery, 2007). I will no longer include lead and lag terms in the model either as the trading volume significantly increases during Phase II of the scheme (see Figure 1). Another alteration from the original model is that I will be running the regressions by phase not in yearly blocks. By running it in phases I am expecting to provide a better comparison of overall trends between Phase I and Phase II. In total I will have 30 (15 firms*2 phases) individual regressions for this supplemental analysis.

Figure 1



*EU Allowances are traded in lots of 1000

IV. Data

I first looked at the same 12 electricity firms that Mo et al. (2012) used for their study: a2a (IT), Drax Group (UK), Électricité de France (FR), Endesa (ES), Enel (IT), Fortum (FI), Iberdrola (ES), International Power (UK), Public Power Corporation (GR), Red Eléctrica de España (ES), Scottish & Southern Energy (UK), Terna Group (IT). The daily stock price data was taken from Reuter's DATASTREAM service and the adjusted price was used for the series. The data series used for the market return was the STOXX Europe 600 Utilities Index, which was also retrieved from DATASTREAM. The data series used for changes in oil prices was the Europe Brent Spot Price (FOB) retrieved from the U.S. Energy Information Administration. Brent is the most relevant traded crude for European energy firms (Oberndorfer 2009). No common market for electricity exists in the EU, but the prevailing literature has used German electricity prices from the European Energy Exchange (EEX) as a proxy. Germany is the biggest electricity market in Europe and the EXX is one of the most liquid European power exchanges. Unable to obtain the electricity contract used by Mo et al. in their research, I used the German electricity futures Phelix month base series from the EEX, the same series that Oberndorfer (2009) used. For this data series I used the prices of contracts that were one month away from expiration. As the explanatory variable of primary interest, the EUA data series was retrieved from the IntercontinentalExchange (ICE). The daily prices of EUA futures contracts that were to expire at the end of the current year were used. EUA prices have developed very similarly in all marketplaces so the choice of marketplace is not of major concern (Oberndorfer, 2009). The definition of the variables and their descriptive statistics are provided in the appendix.

V. Results

The market model was estimated for each sample company from 2006-2012 (details in Table A found in the Appendix section). The aggregate results from the previous literature are compared with those from mine during the 2006-2009 time period in Table 1 and 2.

Table 1

Mean and median β estimates from Mo et al. (2012) for 48 firm-year observations (12 firms*4 years)

	βm (market beta)	βe (electricity price effect)	βo (oil price effect)	βc (EUA price effect)
Mo, et al. Mean (2006-2009)	0.901	0.068	0.042	-0.014
Mo, et al. Median (2006-2009)	0.870	0.058	0.016	-0.021

Table 2

Mean and median β estimates for 48 firm-year observations (12 firms*4 years)

	βm (market beta)	βe (electricity price effect)	βo (oil price effect)	βc (EUA price effect)
Mean (2006-2009)	0.810	-0.002	0.047	-0.003
Median (2006-2009)	0.780	0.001	0.028	-0.002

The mean for B_m was 0.091 smaller in my analysis compared to the prior study, the mean for B_e was 0.070 smaller, the mean for B_o was .005 larger, and the B_c was 0.011 larger. Overall, the results seem to indicate that my model and data replicated the previous study fairly well. The only factor which had a coefficient with a different sign than the previous study was changes in electricity prices. Although it is surprising that the relationship changed from being positively correlated to now slightly negative, the fact that the data series I used for electricity prices was different than the one used in Mo et al.'s analysis explains why variation could exist. It is no surprise that the market beta is by far the most significant factor in the model. The mean β_m value of 0.810 indicates that an increase in the market return of 10% would lead to an increase in the stock return of these firms by 8.1% on average. The β_c value of -0.003 indicates that a change in EUA prices of 10% leads to a 0.03% decrease in stock performance of European electricity firms on average over this period. This is a very small amount indicating that capital markets view the EU ETS as not shrinking the firms' profits very much on average during this time period. But it is important to keep in mind that the carbon price beta estimates did vary greatly from firm to firm, ranging from -0.232 to 0.244.

The mean and median results from when the study is extended to the new time period of interest are presented in Table 3.

Table 3

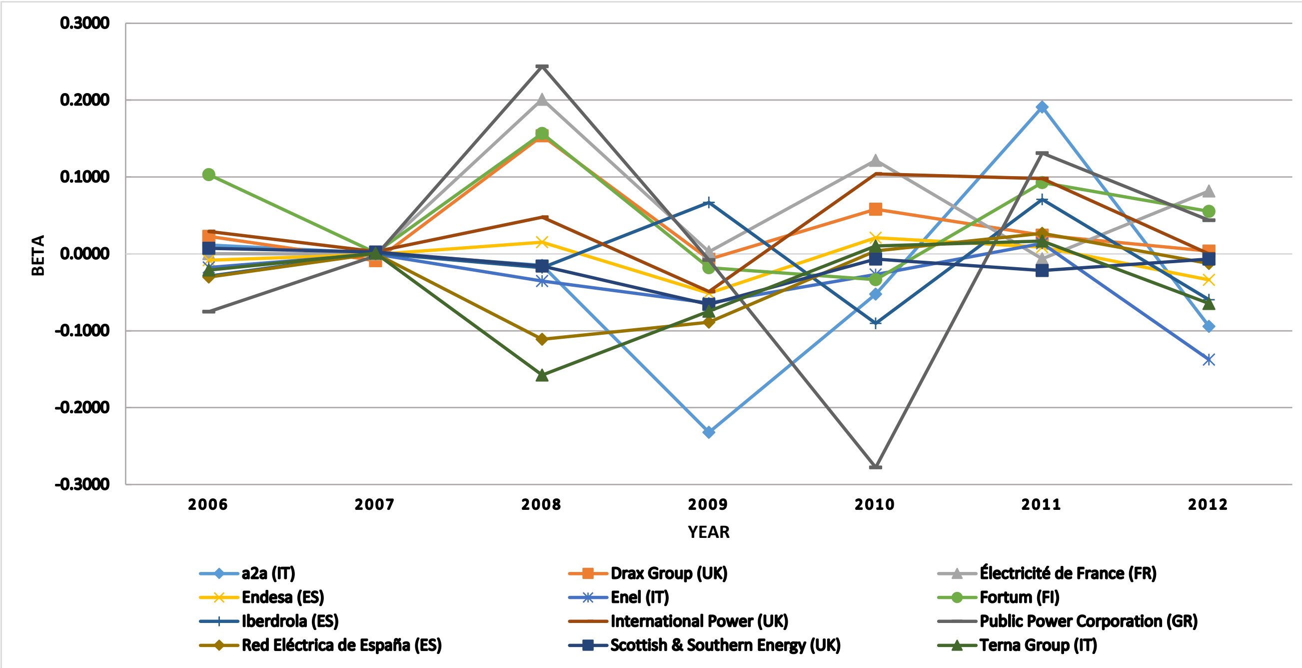
Mean and median β estimates for 36 firm-year observations (12 firms*3 years)

	βm (market beta)	βe (electricity price effect)	βo (oil price effect)	βc (EUA price effect)
Mean (2010-2012)	1.020	0.001	0.020	0.007
Median (2010-2012)	1.040	0.018	-0.005	0.009

The mean for B_m was 0.210 bigger during the 2010-2012 interval compared to my results from the 2006-2009 period, for B_e the mean was 0.003 bigger, for B_o it was -0.027 smaller, and for B_c it was 0.010 bigger. One explanation for why the carbon price beta might have switched from negative to positive is that the electricity firms might have found themselves more often in a net long position in terms of permits in the 2010-2012 time range, which wouldn't be surprising given the surplus of permits in the market. If a firm is in a net long position and the price of EUAs increases, expected future profits will increase as the firm can sell the unneeded permits on the market for a greater amount of revenue. Greater future profits translate into appreciation of stock value. The absolute value is still fairly small, with a 10% increase in EUA prices leading to a .07% increase in stock return on average. This indicates that the capital markets continue to believe the EU ETS does not affect the profits of European electricity firms too significantly. Figure 2 provides a visual of the change in carbon price beta for each firm individually over the entire 2006-2012 period.

Figure 2

The development of β_c from 2006 to 2012 for each firm



As one can see, the variation in the carbon price beta estimates not only varies from one firm to another but varies in an individual firm significantly over time as well. As an example, Public Power Corporation has a carbon price beta of 0.244 in 2008 which changes to -0.278 in 2010. One element of the graph that stands out is the 2007 to 2008 region. The carbon price betas across all firms in 2007 can be characterized by having a value extremely close to zero. One major reason for changes in the price of EUAs having relatively no impact during this year was the banking policy of the EU ETS that did not allow the usage of permits obtained in Phase I to be used in Phase II. EUA prices consistently fell (see Figure 3 below) once the market became aware that there was a surplus present and that the permits were without value when Phase I ended at the end of 2007 (Convery, 2007). Even if changes in EUA prices are large on a percentage basis, the impact the change will have on profits is small if the price of the permits are close to zero like they were for most of 2007. The carbon price beta estimates in 2008 are characterized by a large deviation from the 2007 levels for all firms, some becoming positively correlated, some negatively. This dispersion away from zero can be explained by the price of the permits re-entering the €20-€30 range. For the new period of interest, 2010-2012, there does not seem to be present much of a trend at all on the individual firm level. Some firms' stock value maintain the same type of relationship across all three years while others switch from being positively correlated to negatively correlated or vice versa. This was not consistent with my hypothesis. It appears firms did not establish themselves in the eyes of the capital markets as either being consistently hurt or helped by the scheme during Phase II.

Figure 3

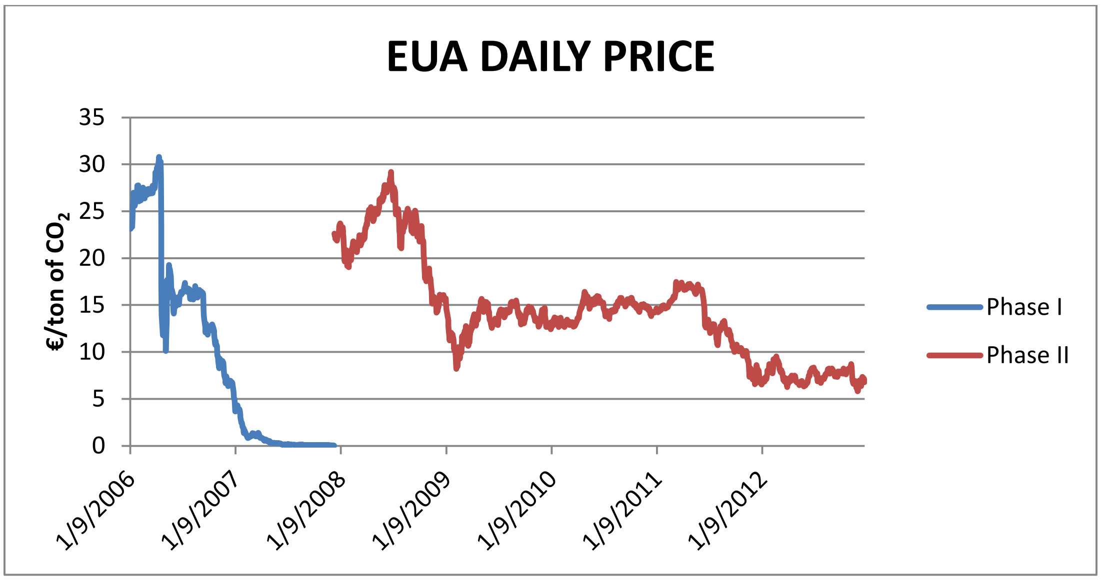


Table 4 presents a summary of the development of the carbon price beta estimates over time on a year by year basis.

Table 4

Development of β_c over time by year

	2006	2007	2008	2009	2010	2011	2012
Mean β_c	0.006	0.000	0.020	-0.053	0.010	0.047	-0.027
Median β_c	0.000	0.001	-0.015	-0.051	0.004	0.024	-0.023

The fluctuation back and forth between a positive and negative mean for carbon price beta estimates in Phase II is surprising. Again, I would have expected a common trend to have established of whether capital markets believe the scheme affects firms' profits positively or negatively. No misspecification tests were completed because the intent of this study was to use the exact same model as that used in Mo et al.'s research.

The supplemental analysis I conducted added three additional firms: CEZ Group (CZ), E.ON (DE), and RWE (DE). The regressions were conducted not in yearly blocks but by the two phases (details in Table B found in the Appendix section). The aggregate results are presented in Table 5 and Table 6.

***Table 5**

Mean and median estimates for 15 firms during Phase I

	βm (market beta)	βe (electricity price effect)	βo (oil price effect)	βc (EUA price effect)
Phase I Mean	0.671	0.008	0.029	0.000
Phase I Median	0.635	0.005	0.007	0.000

*Phase I of the EU ETS began in 2005, but this study only looks at data starting in 2006

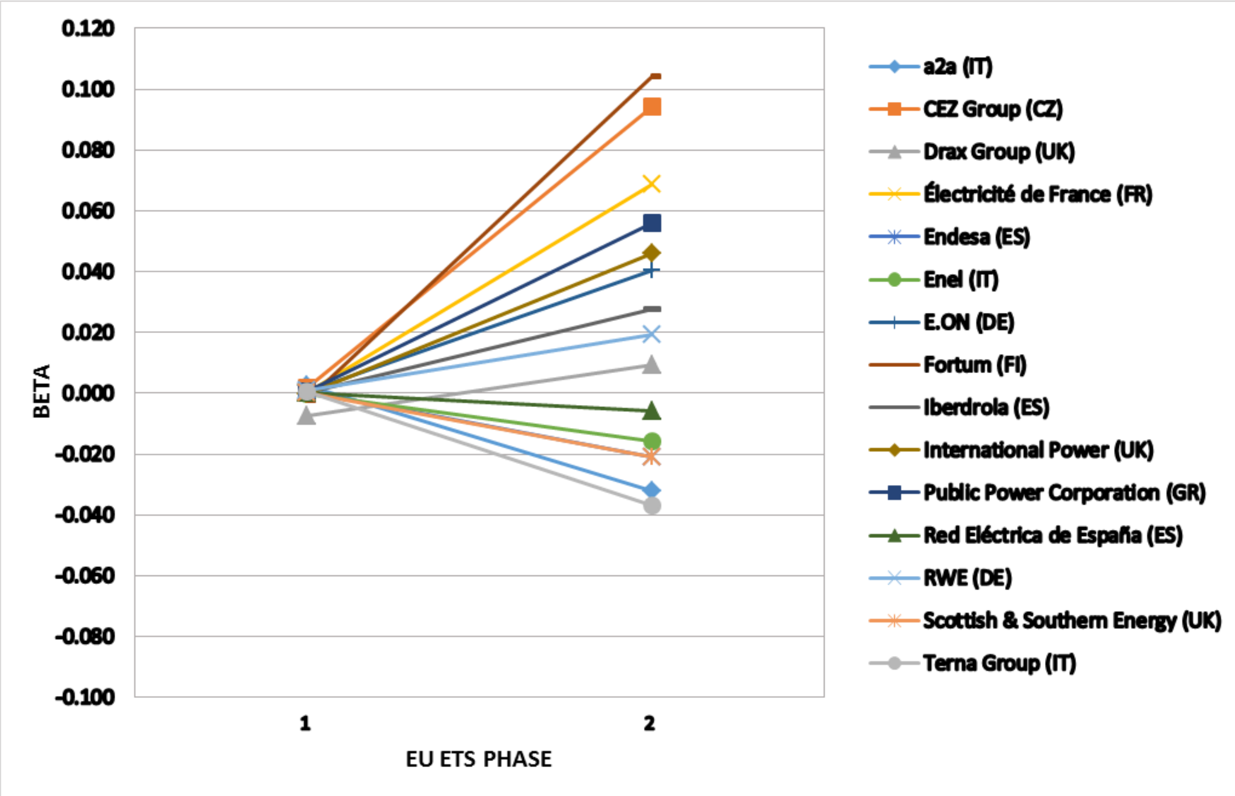
Table 6

Mean and median estimates for 15 firms during Phase II

	βm (market beta)	βe (electricity price effect)	βo (oil price effect)	βc (EUA price effect)
Phase II Mean	0.775	-0.015	0.023	0.022
Phase II Median	0.761	-0.015	0.035	0.019

The results indicate that the mean market beta estimates increased by .104 from Phase I to Phase II, the mean electricity price beta estimates decreased by .023, the mean oil price beta estimates decreased by .006, and the EUA price beta estimates increased by .022. The electricity price beta estimates are surprising. It doesn't seem very reasonable to assume an increase in electricity prices, the source of revenue for these firms, would signal a drop in firm value. The market beta estimates and oil price beta estimates stay fairly consistent from Phase I to Phase II—changing by 15.5% and 20.7% respectively. This makes sense as the only relationship that should be significantly altered by the changes in regulations associated with the EU ETS is the carbon price beta estimate. Given that Oberndorfer (2009) had found the estimated carbon price beta on average for Phase I to be between 0.001 and 0.002 and that Mo et al. (2012) had found it be 0.0055, I was surprised to see my results have a Phase I mean β_c value very close to zero at 0.000. One explanation could be that I used a different mix of firms for my analysis than either prior study. Another explanation of why my results differed from Mo et al. (2012) in particular could be from my model not including lead and lag terms in this supplementary analysis. The value of 0.000 on its own is not surprising to me though, as it was the pilot phase with 95% of permits grandfathered in and the price of EUAs plummeting in the second half of the phase. With EUA prices so low and such a large percentage of permits allocated out for free there is not much opportunity for the scheme to impact profit in such a situation. The increase in the carbon price beta estimate to 0.022 from Phase I to Phase II indicates that of the two countering pressures low electricity demand teamed with possible over-allocation of permits outweighed higher regulation stringency on average. Figure 4 provides a disaggregated look at the evolution of the carbon price beta estimates from Phase I to Phase II.

Figure 4
The development of the carbon price beta from Phase I to Phase II for each firm



Fortum's Phase II βc at 0.104 was the most positive and Terna Group's βc at -0.037 was the most negative. The three firms located in Italy: a2a, Enel, and Terna Group all have negative β_c with values of -0.032, -0.016, and -0.037 respectively. As noted earlier, Italy has one of the most stringent National Allocation Plans. This would make sense then that an Italian electricity firm would find its stock value decrease when the price of EUAs goes up because it is more likely than electricity firms in other countries to have to purchase a higher amount of permits on the market meaning it has higher compliance costs. For Germany, both E.ON and RWE had positive carbon price betas of 0.040 and 0.019 respectively. But for others countries the pattern of either all firms being positively correlated or negatively correlated did not hold true. For Spain, Endesa and Red Eléctrica de España had carbon price beta estimates that were negative but Iberdola had a positive beta. For Britain, Drax Group and International power had carbon price beta estimates that were positive but Scottish & Southern Energy had a negative beta. It is hard to say then whether there are significant country-specific effects involved without doing a panel-type regression approach, which I did not conduct. Table B provides the individual results for all 30 regressions involved in this supplementary analysis. The market return was significant in all 30 regressions, while at a ten percent significance level, changes in electricity prices were significant once, changes in oil prices were significant thirteen times, and changes in EUA prices were significant seven times.

VI. Conclusion

In conclusion, this research extended the study by Mo et al. (2012) through the end of Phase II hoping to better understand the relationship between changes in EUA prices and the stock performance of European electricity firms. I predicted that the correlation would become more positive in the 2010-2012 period of analysis, that I would find country-specific effects, and that a level of consistency would be reached in terms of correlation over time. On an aggregate level, the correlation between changes in EUA prices and stock performance was found to be slightly more positive in the 2010-2012 period versus the 2006-2009 period, with the estimate of the coefficient on carbon price equal to 0.007 instead of -0.003. In the 15 firm analysis, in which I compared Phase I results to Phase II the correlation became more positive as well, with β_c increasing from 0.000 to 0.022. On the disaggregate level, excluding the 3 Italian electricity firms, 9 out of the other 12 in the 15 firm analysis had a positive βc value in Phase II, indicating that capital markets believed most firms could profit from the scheme's regulation. Realizing that the market had a surplus of permits and that the electricity sector has a better ability to pass through costs to consumers through higher prices than other industries this result is not surprising. In terms of country-specific effects there is no clear answer from my analysis given that other than Italy, countries had firms with carbon price beta estimates that were both positive and negative. Oberndorfer (2009) was able to statistically test for country-specific effects by using a panel approach, which I did not conduct here. The major surprise of my analysis came from the level of inconsistency relating to the correlation between changes in EUA prices and stock performance over time. On the aggregate level, β_c varied greatly, fluctuating from as low as -0.053 in 2009 to as high as 0.047 in 2011 and back down to -0.027 in 2012 (see Table 4). On the disaggregate level, the correlation switched from negative to positive or vice versa at least once during the Phase II period for 11 out of the 12 firms in the 12 firm analysis. Another important observation to note is that the sensitivity of firms' stock value to changes in EUA prices did increase significantly from Phase I to Phase II of the EU ETS (see Figure 3).

For a future study, a panel approach would provide deeper insight into the possible sources of why individual firms react differently to changes in EUA prices. Bushnell et al. (2012) noted in her event study that a source of differentiation in terms of reaction to the sharp decline in EUA prices in April 2006 came from the type of power generation the firm was mainly associated with. Firms that primarily relied on coal for electricity generation reacted differently than firms that primarily relied on natural gas, or hydro. In a future analysis then, such characteristics as the firm's country and type of main power generation should be included in the model.

VII. Appendix

Table A

The estimation results of the β_m ,β_e ,β_o ,β_c (84 individual regressions)

Firm	Year	β_m	*P value	β_e	*P value	β_o	*P value	β_c	*P value
a2a (IT)	2006	0.484	0.000	0.054	0.576	0.037	0.871	0.012	0.248
	2007	0.773	0.000	-0.006	0.883	0.012	0.483	0.001	0.141
	2008	0.781	0.000	0.014	0.797	0.026	0.732	-0.015	0.223
	2009	1.028	0.000	0.060	0.729	0.177	0.011	-0.232	0.023
	2010	1.060	0.000	0.004	0.056	-0.039	0.854	-0.052	0.043
	2011	0.902	0.000	0.007	0.886	-0.033	0.731	0.191	0.002
	2012	1.604	0.000	0.072	0.233	0.317	0.849	-0.094	0.733
Drax Group (UK)	2006	0.589	0.000	-0.029	0.853	0.332	0.013	0.023	0.508
	2007	0.684	0.000	-0.039	0.061	0.334	0.002	-0.009	0.000
	2008	0.558	0.000	0.009	0.513	0.295	0.112	0.154	0.208
	2009	0.682	0.000	0.011	0.630	0.126	0.041	-0.007	0.423
	2010	0.793	0.000	0.045	0.730	-0.069	0.744	0.058	0.784
	2011	0.541	0.000	0.154	0.277	0.034	0.101	0.024	0.310
	2012	0.542	0.000	0.063	0.164	0.024	0.925	0.004	0.195
Électricité de France (FR)	2006	1.089	0.000	0.048	0.044	0.148	0.343	0.000	0.508
	2007	0.916	0.000	-0.031	0.479	0.036	0.097	0.000	0.845
	2008	1.056	0.000	-0.067	0.097	0.096	0.712	0.201	0.069
	2009	1.272	0.000	0.009	0.718	-0.088	0.071	0.003	0.226
	2010	1.158	0.000	0.035	0.981	-0.023	0.531	0.122	0.869
	2011	1.297	0.000	-0.071	0.912	0.015	0.335	-0.007	0.263
	2012	1.349	0.000	-0.064	0.566	0.031	0.559	0.082	0.539
Endesa (ES)	2006	1.275	0.000	-0.028	0.467	-0.071	0.025	-0.008	0.442
	2007	0.041	0.007	-0.008	0.100	0.023	0.564	-0.001	0.923
	2008	0.891	0.000	-0.049	0.454	-0.159	0.891	0.015	0.573
	2009	0.892	0.000	0.070	0.783	0.034	0.047	-0.051	0.124
	2010	1.205	0.000	0.052	0.046	-0.045	0.362	0.021	0.865
	2011	1.052	0.000	0.006	0.788	0.093	0.004	0.009	0.345
	2012	1.374	0.000	0.086	0.883	-0.042	0.802	-0.034	0.732
Enel (IT)	2006	0.640	0.000	0.019	0.907	-0.073	0.038	-0.018	0.970
	2007	0.719	0.000	-0.011	0.873	-0.015	0.806	0.000	0.763
	2008	0.986	0.000	0.001	0.062	-0.051	0.776	-0.035	0.989
	2009	0.983	0.000	0.015	0.709	0.025	0.600	-0.064	0.788
	2010	1.032	0.000	0.006	0.707	0.066	0.005	-0.027	0.101
	2011	1.341	0.000	0.130	0.009	-0.087	0.191	0.014	0.882
	2012	1.528	0.000	0.048	0.460	-0.056	0.867	-0.138	0.100
Fortum (FI)	2006	1.305	0.000	0.026	0.065	0.128	0.766	0.103	0.000
	2007	0.870	0.000	0.024	0.265	0.115	0.118	0.002	0.109
	2008	0.906	0.000	-0.009	0.620	0.279	0.019	0.157	0.001
	2009	0.968	0.000	-0.045	0.763	0.245	0.058	-0.018	0.055
	2010	0.606	0.000	0.102	0.789	0.139	0.102	-0.033	0.289
	2011	0.639	0.000	0.038	0.925	0.233	0.019	0.093	0.020
	2012	0.865	0.000	-0.133	0.053	0.117	0.353	0.055	0.058

Table A continued

The estimation results of the β_m ,β_e ,β_o ,β_c (84 individual regressions)

Firm	Year	β_m	*P value	β_e	*P value	β_o	*P value	β_c	*P value
Iberdrola (ES)	2006	1.313	0.000	-0.004	0.969	-0.060	0.169	-0.029	0.063
	2007	1.053	0.000	-0.014	0.857	-0.036	0.446	0.001	0.771
	2008	1.271	0.000	0.027	0.779	-0.050	0.540	-0.018	0.938
	2009	0.884	0.000	0.026	0.652	0.039	0.050	0.067	0.233
	2010	1.425	0.000	-0.041	0.882	0.008	0.448	-0.090	0.235
	2011	1.322	0.000	0.073	0.446	-0.152	0.696	0.071	0.431
	2012	1.944	0.000	-0.037	0.344	-0.197	0.357	-0.060	0.452
**International Power (UK)	2006	1.025	0.000	-0.005	0.594	0.105	0.145	0.029	0.873
	2007	1.281	0.000	0.013	0.063	-0.014	0.061	0.003	0.933
	2008	0.858	0.000	-0.142	0.247	0.279	0.048	0.048	0.197
	2009	1.197	0.000	-0.134	0.133	-0.004	0.503	-0.049	0.405
	2010	0.626	0.000	-0.036	0.279	0.133	0.418	0.104	0.744
	2011	0.647	0.000	0.000	0.925	-0.078	0.525	0.098	0.569
	2012	-	-	-	-	-	-	-	-
Public Power Corporation (GR)	2006	0.171	0.003	0.051	0.120	0.101	0.003	-0.075	0.753
	2007	0.724	0.000	-0.029	0.485	-0.269	0.634	-0.002	0.842
	2008	0.513	0.000	0.049	0.657	-0.032	0.271	0.244	0.860
	2009	0.462	0.001	-0.075	0.734	0.063	0.908	-0.008	0.000
	2010	1.040	0.001	0.167	0.098	0.102	0.372	-0.278	0.045
	2011	1.015	0.000	0.018	0.852	-0.063	0.727	0.131	0.402
	2012	1.450	0.005	-0.599	0.546	0.438	0.853	0.044	0.898
Red Eléctrica de España (ES)	2006	0.516	0.000	0.056	0.146	0.046	0.939	-0.030	0.234
	2007	0.600	0.000	-0.008	0.999	0.164	0.066	0.000	0.750
	2008	0.665	0.000	0.009	0.559	0.053	0.964	-0.111	0.175
	2009	0.538	0.000	0.041	0.444	-0.006	0.668	-0.089	0.091
	2010	1.291	0.000	-0.075	0.398	-0.020	0.640	0.004	0.980
	2011	1.054	0.000	0.070	0.515	-0.005	0.066	0.027	0.800
	2012	1.297	0.000	-0.091	0.051	-0.059	0.859	-0.013	0.106
Scottish & Southern Energy (UK)	2006	0.745	0.000	0.018	0.231	-0.009	0.581	0.007	0.151
	2007	0.914	0.000	-0.015	0.639	-0.039	0.053	0.002	0.708
	2008	0.779	0.000	-0.078	0.379	-0.048	0.650	-0.016	0.148
	2009	0.572	0.000	-0.006	0.811	-0.018	0.018	-0.066	0.039
	2010	0.664	0.000	-0.011	0.637	-0.105	0.223	-0.007	0.932
	2011	0.497	0.000	0.035	0.218	0.155	0.964	-0.022	0.664
	2012	0.363	0.000	-0.042	0.659	0.011	0.569	-0.007	0.682
Terna Group (IT)	2006	0.690	0.000	0.015	0.505	-0.043	0.207	-0.021	0.055
	2007	0.777	0.000	0.002	0.973	-0.058	0.223	0.001	0.518
	2008	0.555	0.000	0.078	0.989	0.052	0.953	-0.158	0.300
	2009	0.386	0.000	-0.007	0.348	0.030	0.378	-0.075	0.000
	2010	0.619	0.000	-0.042	0.060	-0.075	0.139	0.010	0.148
	2011	0.692	0.000	0.044	0.475	-0.081	0.983	0.017	0.118
	2012	0.861	0.000	0.031	0.244	0.003	0.656	-0.065	0.674

*P values were calculated by using the P value of the synchronous term alone. Method for calculating P value used by *Mo, etc.* was not obtained

**International Power was acquired in April 2012, so 2012 International Power stock market data was omitted from study

Table B

The estimation results of the β_m ,β_e ,β_o ,β_c (30 individual regressions)

Firm	EU ETS Phase	β_m	P value	β_e	P value	β_o	P value	β_c	P value
a2a (IT)	1	0.634	0.000	0.006	0.628	-0.002	0.941	0.002	0.115
	2	0.785	0.000	0.011	0.651	0.040	0.151	-0.032	0.182
CEZ Group (CZ)	1	0.947	0.000	0.026	0.136	0.117	0.002	0.002	0.358
	2	0.642	0.000	0.000	0.997	0.109	0.000	0.094	0.000
Drax Group (UK)	1	0.644	0.000	-0.021	0.227	0.154	0.000	-0.007	0.000
	2	0.529	0.000	0.025	0.262	0.073	0.005	0.009	0.675
Électricité de France (FR)	1	0.621	0.000	0.027	0.089	0.061	0.083	0.000	0.967
	2	0.880	0.000	-0.053	0.008	0.005	0.816	0.069	0.001
Endesa (ES)	1	0.437	0.000	0.001	0.946	-0.059	0.033	0.001	0.731
	2	0.755	0.000	-0.012	0.527	0.035	0.114	-0.021	0.282
Enel (IT)	1	0.565	0.000	0.001	0.861	-0.021	0.246	0.000	0.747
	2	0.994	0.000	0.012	0.477	0.009	0.660	-0.016	0.352
E.ON (DE)	1	0.770	0.000	-0.007	0.584	-0.015	0.611	0.001	0.672
	2	0.959	0.000	-0.029	0.135	0.038	0.088	0.040	0.037
Fortum (FI)	1	0.492	0.000	0.030	0.044	0.096	0.004	-0.002	0.209
	2	0.755	0.000	-0.030	0.129	0.086	0.000	0.104	0.000
Iberdrola (ES)	1	0.858	0.000	-0.005	0.681	-0.042	0.164	0.000	0.905
	2	1.198	0.000	-0.021	0.263	-0.041	0.060	0.028	0.143
International Power (UK)	1	1.086	0.000	0.024	0.101	0.070	0.035	0.000	0.909
	2	0.761	0.000	-0.058	0.016	0.072	0.007	0.046	0.062
Public Power Corporation (GR)	1	0.742	0.000	0.000	0.993	-0.008	0.863	0.001	0.818
	2	0.825	0.000	0.005	0.906	-0.085	0.062	0.056	0.160
Red Eléctrica de España (ES)	1	0.537	0.000	0.005	0.719	0.033	0.275	0.000	0.913
	2	0.652	0.000	-0.017	0.343	0.004	0.862	-0.006	0.740
RWE (DE)	1	0.635	0.000	0.018	0.169	-0.005	0.860	0.001	0.531
	2	0.856	0.000	-0.025	0.173	0.036	0.089	0.019	0.293
Scottish & Southern Energy (UK)	1	0.672	0.000	0.007	0.547	0.050	0.046	0.000	0.823
	2	0.572	0.000	-0.015	0.336	-0.022	0.221	-0.021	0.186
Terna Group (IT)	1	0.422	0.000	0.004	0.690	0.007	0.770	0.000	0.724
	2	0.462	0.000	-0.013	0.417	-0.010	0.571	-0.037	0.020

Table C

Definitions

R_i	The individual European electricity firm's return: $\ln(price_t/price_{t-1})$
R_m	The market return: $\ln(price_t/price_{t-1})$
R_e	The change in electricity prices: $\ln(price_t/price_{t-1})$
R_o	The change in oil prices: $\ln(price_t/price_{t-1})$
R_c	The change in EUA prices: $\ln(price_t/price_{t-1})$

*source of each data series presented in Section IV

Table D

Descriptive Statistics

	mean	st. dev.	min	max
R_m	-0.017%	1.434%	-9.914%	14.858%
R_e	-0.025%	3.069%	-14.988%	27.585%
R_o	0.033%	2.294%	-16.832%	19.819%
R_c	-0.481%	7.664%	-138.629%	138.629%

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